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Effects of Early Season Nitrogen on Grass–Clover Swards in the Northeastern USA

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ABSTRACT

Grass–legume pastures that rely on biologically fixed N are often N deficient in the spring. Early season N applications to grass–clover pastures can help overcome this deficiency. Our objective was to test the effects of early season N application and harvest height on total dry matter (DM) yield and clover fraction of a grass–clover sward in the northeast USA. The study was conducted for 3 yr (1996–1998) at the Russell Larson Agricultural Research Center in Rock Spring, PA (40°48′N, 77°52′W; 330 m above sea level). The soil on the site is a Hagerstown silt loam (Typic Hapludalf, fine, mixed, mesic). The effect of early season N fertilization (0, 22.4, 44.8, and 89.6 kg ha^{-1}) was measured on an orchardgrass (*Dactyls glomerata* L. cv. Pennlate)–white clover (*Trifolium repens* L. cv. Will) sward harvested at three sward heights (15, 22.5, and 30 cm). Increasing N fertilization and target sward harvest height (TSHH) generally increased the early season total DM yield and reduced the clover fraction in the sward. However, by the end of the growing season, the clover fraction from the fertilized treatments was identical to that of the unfertilized treatments. Total early season DM yields on mixed grass–clover swards were increased by 20% with an application of 45 kg N ha^{-1}. Also, maintaining a 15-cm TSHH along with 45 kg N ha^{-1} would maximize the clover fraction in the sward.

To maintain farm profitability and reduce workloads, a growing number of dairy farmers in the northeast USA are adopting grass-based production systems (Fales et al., 1992). Such systems often use cool season grass–legume pastures to provide the bulk of the feed from April to October. However, pastures that rely on biologically fixed N as their main source of N are often N deficient in the spring. This is because the biological processes that provide N to the sward (fixation and mineralization) are temperature dependent (Nannipieri et al., 1985; O'Conner, 1974; Van Berg et al., 1981). Thus, grazing in the spring can be delayed until temperatures increase to the minimal level needed to provide adequate fixed N for plant growth.

The poor spring growth of white clover–grass pastures has been well documented in the UK and New Zealand (Frame and Boyd, 1986; Field and Ball, 1978). To overcome this period of poor growth, researchers have developed programs of spring N applications to white clover–perennial ryegrass (*Lolium perenne* L.) pastures (Morrison et al., 1983; Frame and Boyd, 1987; Field and Ball, 1978; Laidlaw, 1980). In general, these N applications tend to increase overall production, decrease differences in seasonal production, increase the grass portion of the sward, decrease the clover portion of the sward, and decrease N fixation by the clover (Crush et al., 1982; Dennis and Woledge, 1985; Simpson et al., 1988; Wilman and Hollington, 1985; Woledge, 1988). The reason for the decreased clover portion is the increased competition for light brought on by the stimulated growth of the grass (Dennis and Woledge, 1985). This response is independent of white clover variety (Caradus et al., 1993; Laidlaw, 1980) and is less when N is applied as cattle (*Bos taurus*) slurry than when it is applied as mineral fertilizer (Nesheim et al., 1990). However if N application is too high, the clover portion of the sward becomes too low to provide sufficient N to the sward later in the growing season (Caradus et al., 1993; Thomas, 1992).

Because the benefit of early season N applications is greatest when temperature is low (Ledgard et al., 1989), the benefit of such applications should be greater in the temperate continental climate of the northeast USA than in the temperate maritime climates of the UK and

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Abbreviations: DM, dry matter; TSHH, target sward harvest height.

New Zealand where the early growing season temperatures are often higher. Thus, if spring soil N levels are limiting and an optimal level of spring N application can be determined, northeast USA farmers could begin grazing earlier in the spring and still maintain a desirable level of clover for sustained summer and fall production.

Our objective was to determine the influence of early season N application on total dry matter (DM) yield and the clover fraction of a mixed grass–clover sward in the northeast USA.

MATERIALS AND METHODS

The study was conducted for 3 yr (1996–1998) at the Russell Larson Agricultural Research Center in Rock Spring, PA (40°48′N, 77°52′W; 330 m above sea level). The soil on the site is a Hagerstown silt loam (Typic Hapludalf, fine, mixed, mesic). The pH of the plot area was 6.5, and P and K levels were in the medium range.

A binary mixture of a ladino-type white clover and orchardgrass was sown into a conventionally prepared seedbed in August 1995. The white clover was inoculated before seeding, and white clover and orchardgrass were sown at 2.2 and 11.1 kg ha^{-1}, respectively.

In spring of 1996, plots (2.4 by 6.1m) were established in a randomized complete block design with four replications. The treatments consisted of a complete factorial of four N rates (0, 22.4, 44.8, and 89.6 kg ha^{-1}) and three target sward harvest heights (TSHH; 15, 22.5, and 30 cm).

Nitrogen was applied as ammonium nitrate (NH_4NO_3) in early spring, just as the sward began to grow (28 Mar. 1996, 13 Mar. 1997, and 19 Mar. 1998). Each year, all treatments received 30 and 112 kg ha^{-1} P and K, respectively, at the same time the N was applied. When the mean vegetation height in all replications of a treatment reached the TSHH, all plots in a treatment were sampled by harvesting two 60- by 60-cm quadrats at a 7.5-cm stubble height with hand clippers from representative areas of the plots. After sampling, all herbage was clipped to 7.5 cm and removed from the plot. During the remainder of the growing season, plots of each treatment were sampled in the same manner, and herbage was removed as often as it reached the TSHH. After each harvest, samples were hand-separated into grass and clover components, dried at 60°C, and weighed. Samples were then ground and analyzed for N using direct combustion by The Pennsylvania State University Agricultural Analytical Services Laboratory (Campbell, 1991).

Data from individual harvests in April and May were summed to obtain early season DM yield and clover fraction. The number of individual harvests included in the early season harvest was unaffected by N fertilization, but it decreased with TSHH from an average high of three harvests per year for the 15-cm TSHH to an average low of two harvests per year at the 30-cm TSHH. Data from all harvests were summed to obtain full-season DM yield and clover fraction. As with the early season data, the number of individual harvests included in the full season was unaffected by N fertilization but decreased with TSHH. Over the 3 yr of the study, there were approximately 12, 9, and 7 harvests included in the full-season data for 15-, 22.5-, and 30-cm TSHHs, respectively.

Weather data were recorded on site (Stevensen and Pennypacker, 1996, 1997, 1998). Long-term weather data was taken from the Centre County Soil Survey report (USDA, 1981). Both the effect of the individual treatments on the dependant variables and the nature of the response of the dependant variables to N fertilization rate and TSHH were determined (Neter et al., 1990) using the GLM procedure in SAS (SAS, 1998). Least-square means of the individual treatment effects were separated using the pdiff option in the LSMEANS statement within the GLM procedure. The nature of the response was determined using linear, quadratic, and cubic contrasts developed for N fertilization rate and linear and quadratic contrasts developed for TSHH.

RESULTS

Yearly Weather Effects

Temperatures and precipitation for the three study years are summarized in Table 1. Temperature patterns were consistent over the 3 yr of the study. However, precipitation amounts and patterns differed among years of the study. Precipitation during the April through September growing season was 892 mm in 1996, but only 540 and 624 mm in 1997 and 1998, respectively. The lesser amounts of precipitation in 1997 and 1998 were close to the long-term average for this locality. In 1996, precipitation was somewhat evenly distributed. Precipitation was low early in the 1997 growing season and increased near the end. In 1998, the bulk of the precipitation came in April through June, and drought conditions occurred in the remainder of the growing season. These differences contributed to the significant year × main effect interactions observed in early season total DM yields and early season clover fraction of the harvested herbage. As a result, total DM yields and clover fraction are analyzed within each year. There was no N rate × TSHH interaction within or over years for either early season total DM yield or clover fraction or full-season total DM yield or clover fraction. Consequently, con-

Table 1. Weather summary for Rock Spring, PA, for 1996, 1997, and 1998.

Month	1996	1997	1998	30-yr avg.
	Monthly precipitation			
	mm			
Jan.	117	25	88	59
Feb.	48	34	91	53
Mar.	94	83	67	87
Apr.	99	28	172	85
May	77	100	116	102
June	126	59	131	85
July	132	61	89	90
Aug.	140	171	71	87
Sept.	319	122	44	66
Oct.	126	13	20	70
Nov.	86	187	9	83
Dec.	119	39	5	66
Total	1483	922	903	933
	Avg. ambient temperature			
	°C			
Jan.	−4.6	−3.7	2.1	−2.7
Feb.	−2.5	1.1	1.2	−2.1
Mar.	−0.1	3.1	4.6	2.5
Apr.	9.0	7.6	10.0	9.5
May	13.2	11.9	17.0	15.3
June	20.5	19.4	18.5	20.0
July	20.1	20.9	20.7	22.1
Aug.	19.9	19.1	20.9	21.1
Sept.	16.3	15.4	18.6	17.1
Oct.	10.3	10.2	10.7	11.5
Nov.	1.6	3.1	6.1	5.0
Dec.	0.6	−0.2	2.6	−1.3
Avg.	8.7	9.0	11.1	9.8

Table 2. Summary of N fertilization and target sward harvest height (TSHH) for early and full season dry matter (DM) yields and clover function.

	1996	1997	1998	1996–1998
		Early season total DM yield		
N rate linear	*	NS	*	*
N rate quadratic	NS	NS	NS	NS
N rate cubic	NS	NS	NS	NS
TSHH linear	*	NS	*	*
TSHH quadratic	NS	NS	NS	NS
		Early season clover fraction		
N rate linear	*	*	*	*
N rate quadratic	*	*	*	*
N rate cubic	NS	NS	NS	NS
TSHH linear	NS	*	*	*
TSHH quadratic	NS	NS	NS	NS
		Full-season total DM yields		
N rate linear	*	NS	*	*
N rate quadratic	NS	NS	NS	NS
N rate cubic	NS	NS	NS	NS
TSHH linear	*	*	NS	*
TSHH quadratic	*	NS	*	NS
		Full-season clover fraction		
N rate linear	*	*	*	*
N rate quadratic	NS	NS	NS	NS
N rate cubic	NS	NS	NS	NS
TSHH linear	NS	*	*	*
TSHH quadratic	NS	NS	NS	NS

* Significant at the 0.05 level.

trasts are summarized only for the main effects (Table 2).

Early Season Production

There were linear increases due to N fertilization in early season total DM yields in 1996 and 1998 but not in 1997 (Tables 2 and 3). In 1997, April–June precipitation (187 mm) was 31% less than the 30-yr average (272 mm). Consequently, there was no increase in total DM yields due to N fertilization in 1997 (Table 3). In contrast to 1997, April–June precipitation was 11 and 54% greater than the 30-yr average in 1996 and 1998, respectively. As a result, early season total DM yields increased 57 and 58% at the 89.6 kg N ha^{-1} fertilizer rate in 1996 and 1998, respectively.

Although there was no response in total DM yield to N fertilization in 1997, total DM yields were higher than in the other years. We attribute this to the lower April–June average ambient temperature in 1997 (12.9°C) being more conducive to the growth of white clover than in 1996 or 1998 when April–June average ambient temperatures were 14.2 and 15.2°C, respectively. This is illustrated in Table 4 where clover fraction was highest in 1997 when the April–June average ambient temperature was lowest and clover fraction was lowest in 1998 when the April–June average ambient temperature was highest (Table 1). In an environment conducive to white clover growth, the effect of fertilizer N would be diminished because of biological N fixation.

There were linear increases in early season total DM yields as TSHH increased in 1996 and 1998 but not in 1997 (Tables 2 and 3). This was similar to the response in early season total DM yield to N fertilization, with increases being observed in years with the highest April–June precipitation and temperatures. Increasing TSHH from 15 to 30 cm increased early season total DM yield by 106 and 33% in 1996 and 1998, respectively. In 1997, when cooler average ambient temperatures were favorable to white clover growth and early season clover fraction was highest (Table 4), TSHH had no effect on total DM yields.

Averaged over the 3 yr of the study, there was a

Table 3. Effect of N rate and target sward harvest height (TSHH) on early season (April–May) total dry matter (DM) yields over 3 yr.

	N Rate, kg ha^{-1}				
	0	22.4	44.8	89.6	Mean
		1996 total DM yields, Mg ha^{-1}			
TSHH, cm					
15	0.78	0.91	1.22	1.48	1.10 (0.8)†c*
22.5	1.32	1.12	1.48	1.85	1.44 (0.7)b
30	1.66	2.38	2.47	2.55	2.27 (.11)a
Mean	1.25 (1.2)d	1.47 (.20)c	1.72 (1.7)b	1.96 (.15)a	
		1997 total DM yields, Mg ha^{-1}			
15	2.52	2.36	2.76	2.68	2.58 (.10)a
22.5	2.66	2.77	3.00	3.10	2.88 (.17)a
30	2.59 (.15)a	2.91 (.18)a	2.96 (.16)a	3.15 (.19)a	2.90 (.17)a
		1998 total DM yields, Mg ha^{-1}			
15	1.49	2.00	2.26	2.13	1.97 (.11)b
22.5	1.44	1.65	1.93	2.42	1.86 (.12)b
30	2.14	2.20	2.68	3.47	2.62 (.15)a
Mean	1.69 (.12)c	1.95 (.10)c	2.29 (.12)b	2.67 (.20)a	
		1996–1998 total DM yields, Mg ha^{-1}			
15	1.60	1.76	2.08	2.10	1.88 (.10)b
22.5	1.81	1.85	2.14	2.46	2.06 (.11)b
30	2.13	2.50	2.71	3.06	2.60 (.09)a
Mean	1.84 (.12)b	2.03 (.13)b	2.31 (.12)a	2.54 (.12)a	

* Means in the same row or column within years followed by the same letter are not significantly different ($P > 0.05$).
† Values in parentheses are the standard error of the mean.

Table 4. Effect of N rate and target sward harvest height (TSHH) on early season (April–May) clover fraction yields over 3 yr.

	N Rate, kg ha^{-1}				
	0	22.4	44.8	89.6	Mean
		1996 clover fraction			
TSHH, cm					
15	0.33	0.28	0.24	0.16	0.24 (.02)†a*
22.5	0.43	0.22	0.14	0.18	0.24 (.03)a
30	0.41	0.28	0.24	0.13	0.27 (.03)a
Mean	0.39 (.03)a	0.26 (.02)b	0.21 (.02)bc	0.14 (.02)c	
		1997 clover fraction			
15	0.57	0.60	0.46	0.36	0.50 (.03)a
22.5	0.61	0.45	0.42	0.44	0.48 (.03)a
30	0.52	0.43	0.33	0.27	0.39 (.03)b
Mean	0.57 (.02)a	0.49 (.02)a	0.40 (.03)b	0.36 (.03)b	
		1998 clover fraction			
15	0.14	0.17	0.10	0.07	0.12a
22.5	0.20	0.11	0.08	0.06	0.11a
30	0.16	0.07	0.04	0.03	0.08b
Mean	0.17 (.02)a	0.12 (.02)b	0.07 (.01)c	0.05 (.01)c	
		1996–1998 clover fraction			
15	0.35	0.35	0.27	0.18	0.29 (.03)a
22.5	0.42	0.26	0.21	0.23	0.28 (.03)a
30	0.36	0.26	0.20	0.15	0.24 (.02)b
Mean	0.37 (.03)a	0.29 (.03)b	0.23 (.03)c	0.18 (.02)d	

* Means in the same row or column within years followed by the same letter are not significantly different ($P > 0.05$).
† Values in parentheses are the standard error of the mean.

significant linear response in early season total DM yield due to N fertilization and TSHH (Tables 2 and 3). Nitrogen fertilization increased early season total DM yield 26 and 38% at the 44.8 and 89.6 kg N ha^{-1} fertilization rates, respectively. However, there was no difference in early season total DM yield between the 44.8 and 89.6 kg N ha^{-1} fertilization rates. Increasing TSHH from 15 to 30 cm increased early season total DM yield by 38%.

There were significant linear and quadratic effects in the response of early season clover fraction to N fertilization (Tables 2 and 4). In general, increasing N fertilization decreased fraction of early season clover N. Because of the previously discussed combined influences of precipitation and temperature, the decrease was only 36% in 1997 but was 64 and 71% in 1996 and 1998, respectively. Averaged over the 3 yr of the study, N fertilization decreased early season clover fraction by as much as 50% at the highest N application rate, 89.6 kg N ha^{-1}.

There was a significant inverse linear response of early season clover fraction to increasing TSHH in 1997 and 1998 but not in 1996 (Tables 2 and 4). Increasing TSHH from 15 to 30 cm decreased early season clover fraction by 22 and 33% in 1997 and 1998, respectively. In 1996, increasing TSHH increased clover fraction, but the increase was not large enough to be significant. Over the course of the study, increasing TSHH from 15 to 30 cm decreased early season clover fraction by 17%, but increasing TSHH to only 22.5 cm had no significant effect on early season clover fraction.

Full Season

There were linear increases due to N fertilization in full-season total DM yields in 1996 and 1998 but not in 1997 (Tables 2 and 5). The pattern of these linear effects was the same as those observed in early season total DM yields. This indicates that the effect of the early season N applications was confined to spring. This is supported by herbage N concentrations (Fig. 1). After the initial effect of fertilizer N was dissipated in June, N concentrations in the grass component of the sward remained relatively constant at all N fertilization rates and TSHHs over the remainder of the growing season. In contrast, the N concentration in the clover portion of the sward continued to decrease at the highest TSHH.

There were linear and quadratic effects of TSHH on full-season total DM yield in 1996 and in 1998 but only linear effects of TSHH on full-season DM yield in 1997 (Tables 2 and 5). In 1996, there was abundant precipitation throughout the growing season, but in 1997, precipitation was below normal in the spring and above normal the rest of the year (Table 1). In 1998, there was a quadratic effect on full-season total DM yield resulting from TSHH having an inconsistent effect on DM yield at all N fertilization rates.

Averaged over the 3 yr of the study, there were linear effects of N fertilization rate and TSHH on full-season total DM yield (Tables 2 and 5). Increasing N fertilization increased full-season total DM yield by 6% at the 89.6 kg N ha^{-1} fertilization rate (Table 5). Increasing

Table 5. Effect of N rate and target sward harvest height (TSHH) on full-season (April–September) total dry matter (DM) yields over 3 yr.

	N Rate, kg ha^{-1}				
	0	22.4	44.8	89.6	Mean
		1996 total DM yields, Mg ha^{-1}			
TSHH, cm					
15	8.08	7.92	8.16	8.11	8.07 (.13)†b*
22.5	8.11	8.68	8.74	9.79	8.83 (.18)a
30	8.63	9.06	9.13	8.59	8.85 (.18)a
Mean	8.27 (.17)b	8.55 (.22)ab	8.68 (.17)ab	8.83 (.27)a	
		1997 total DM yields, Mg ha^{-1}			
15	6.67	6.42	6.65	6.50	6.56 (.09)b
22.5	6.88	7.10	7.21	7.20	7.10 (.23)b
30	8.00	8.07	7.69	7.97	7.94 (.18)a
Mean	7.19 (.29)a	7.20 (.29)a	7.18 (.21)a	7.22 (.28)a	
		1998 total DM yields, Mg ha^{-1}			
15	6.15	6.98	7.18	6.57	6.72 (.21)a
22.5	5.40	5.60	5.36	6.08	5.61 (.14)c
30	6.10	5.78	5.78	6.82	6.12 (.20)b
Mean	5.88 (.25)bc	6.12 (.27)ac	6.11 (.29)ac	6.49 (.16)a	
		1996–1998 total DM yields, Mg ha^{-1}			
15	6.97	7.11	7.33	7.06	7.12 (.13)b
22.5	6.80	7.12	7.10	7.69	7.18 (.22)b
30	7.58	7.64	7.53	7.80	7.34 (.20)a
Mean	7.11 (.21)b	7.29 (.22)ab	7.32 (.22)ab	7.51 (.21)a	

* Means in the same row or column within years are not significantly different ($P > 0.05$).

† Values in parentheses are the standard error of the mean.

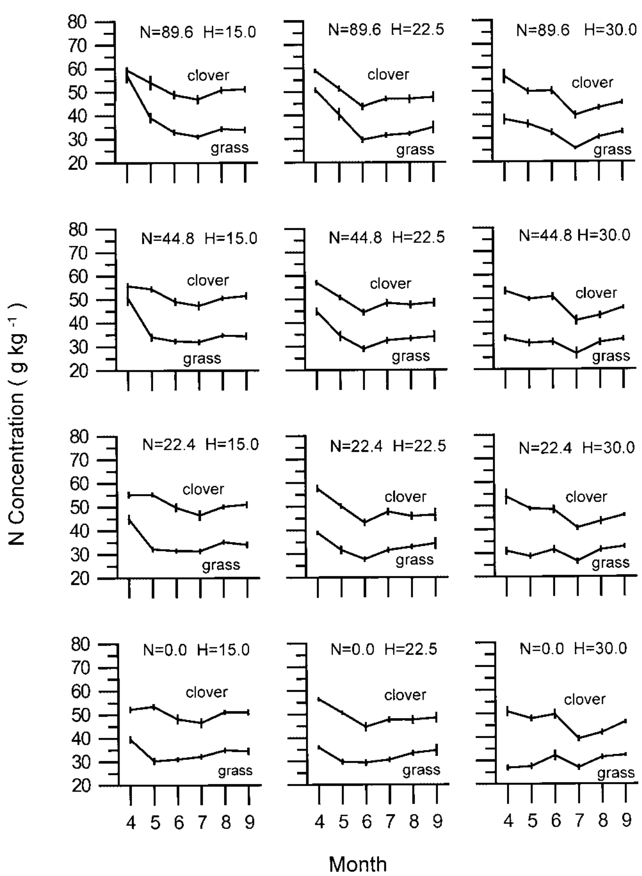

Fig. 1. Monthly N concentrations in grass and clover fractions of orchardgrass–white clover swards fertilized with four rates of N and harvested at three target sward harvest heights (TSHH). Vertical bars indicate standard error of the mean.

Table 6. Effect of N rate and target sward harvest height (TSHH) on full-season (April–September) clover fraction over 3 yr.

	N Rate, kg ha^{-1}				
	0	22.4	44.8	89.6	Mean
			1996 clover fraction		
TSHH, cm					
15	0.60	0.64	0.57	0.45	0.56 (.02)†a*
22.5	0.64	0.56	0.51	0.49	0.55 (.02)a
30	0.65	0.59	0.54	0.44	0.55 (.03)a
Mean	0.63 (.02)a	0.60 (.02)a	0.54 (.02)b	0.46 (.02)c	
			1997 clover fraction		
15	0.57	0.59	0.51	0.44	0.53 (.02)a
22.5	0.60	0.52	0.48	0.47	0.52 (.02)a
30	0.52	0.47	0.41	0.37	0.44 (.02)b
Mean	0.56 (.02)a	0.53 (.02)a	0.47 (.02)b	0.42 (.02)c	
			1998 clover fraction		
15	0.36	0.42	0.33	0.28	0.34 (.02)a
22.5	0.39	0.31	0.26	0.21	0.29 (.03)ab
30	0.42	0.28	0.22	0.17	0.27 (.03)b
Mean	0.39 (.02)a	0.34 (.03)a	0.27 (.03)b	0.22 (.03)b	
			1996–1998 clover fraction		
15	0.51	0.55	0.47	0.39	0.48 (.02)a
22.5	0.54	0.46	0.42	0.39	0.45 (.02)b
30	0.53	0.45	0.39	0.33	0.42 (.02)c
Mean	0.53 (.02)	0.49 (.02)	0.43 (.02)	0.37 (.02)	

* Means in the same row or column within years are not significantly different ($P > 0.05$).
† Values in parentheses are the standard error of the mean.

TSHH from 15 to 30 cm increased full-season total DM yield by 3%.

There was a liner effect of N fertilization on full-season clover fraction in all 3 yr (Tables 2 and 6). Increasing N fertilization decreased full-season clover fraction 27, 25, and 44% in 1996, 1997, and 1998, respectively (Table 6). Over the 3 yr of the study, increasing N fertilization decreased full-season clover fraction by 30%. This is in contrast to the 50% early season clover fraction reduction caused by N fertilization (Table 4). This was because, as previously discussed, the effect of early season N fertilization did not extend beyond June. In fact, as the season progressed, clover fraction at all N fertilization rates and TSHHs tended to converge to 0.50 by the end of the season (Fig. 2).

There was a linear effect by TSHH on full-season clover fraction in 1997 and 1998 but not in 1996 (Tables 2 and 6). In 1997 and 1998, increasing TSHH from 15 to 30 cm decreased full-season clover fraction by 17 and 21%, respectively. Over the 3 yr of the study, increasing TSHH from 15 to 22.5 and 30 cm decreased full-season clover fraction by 6.3 and 12.5%, respectively.

DISCUSSION

The benefit of an early season N application to mixed grass–clover pastures is to increase early season yields while minimizing the decrease of clover in the sward. Our results suggest there was no benefit to early season total DM yield from applying more than 44.8 kg N ha^{-1} (Table 3). Maximizing early season clover fraction at this N application rate would require grazing at the 15-cm height. Above this TSHH, the clover fraction decreased rapidly. At the 15-cm TSHH, the application of 44.8 kg N ha^{-1} increased early season total DM yields from 1.60 to 2.08 Mg ha^{-1}, an increase of 21%.

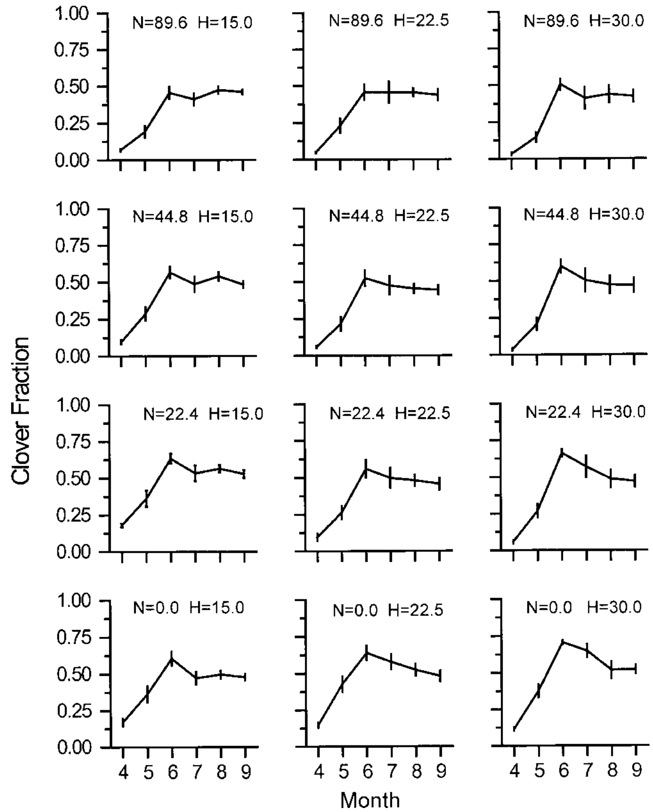

Fig. 2. Monthly clover fraction of orchardgrass–white clover swards fertilized with four rates of N and harvested at three target sward harvest heights (TSHH). Vertical bars indicate standard error of the mean.

The effect of a 44.8 kg N ha^{-1} fertilizer N application was short lived. Nitrogen concentration in grass DM yields over the season showed the effect of N fertilization to be largely dissipated after the first month of production. This rate of N use agrees with that from a previous N study in the same geographic area on a similar soil type where fertilizer N accumulation and fertilizer N use efficiency of orchardgrass receiving 42 kg N ha^{-1} in the spring were determined to be about 0.27 kg ha^{-1} day^{-1} and 24%, respectively (Stout and Jung, 1992). At this use efficiency and N uptake rate, the effect of the 44.8 kg N ha^{-1} treatment in this study would last only about 37 d.

Concern with early season N applications to mixed grass–clover swards is the effect on the clover fraction of the sward over the season. Clover fraction data indicate that neither N fertilization nor TSHH had any significant effect on the clover fraction in herbage harvested from the sward in fall. The average clover fraction from all N fertilization rates at all TSHHs in September was 0.46, the same ($P > 0.05$) as that observed at the 0 kg N ha^{-1} application rate cut at 15 cm in the spring.

CONCLUSIONS

Early season DM yields from mixed grass–clover pasture could be increased by about 20% with an application of about 45 kg N ha^{-1}. Also, by starting to graze at a 15-cm height, the clover fraction in the sward would be maximized. In addition to increasing early season DM yield, N application to selected paddocks within a grazing system would help set up a grazing schedule that would better distribute pasture production over the whole grazing season. The benefits of early season fertilization of grass–clover pasture to a particular farm should be evaluated in regard to the forage needs of the particular livestock production enterprise. The amount and quality of stored forages, the price and quality of off-farm forages, and the cost of fertilizer N are a few of the factors that need to be evaluated when considering early season N application.

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